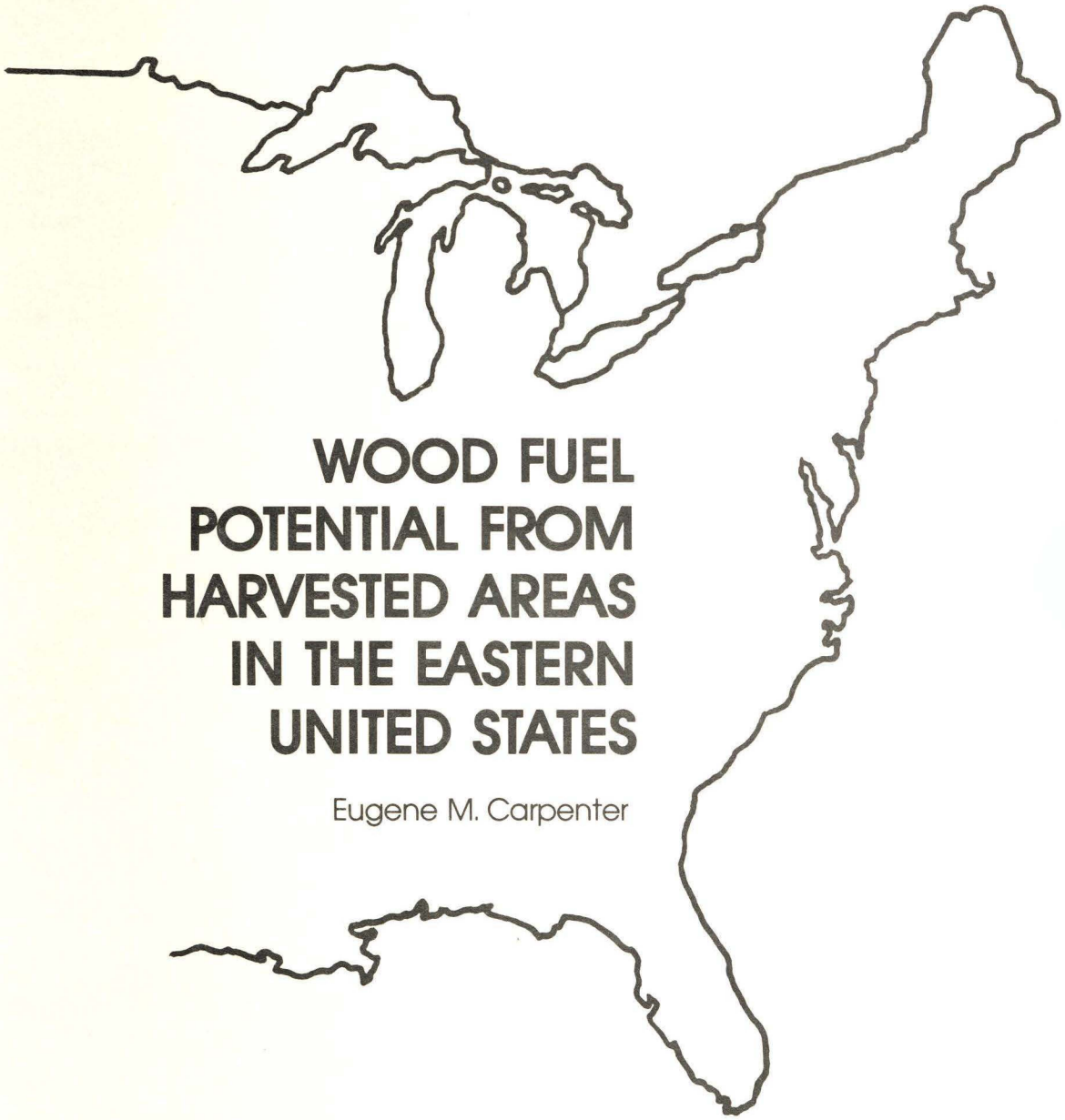
USDA FOREST SERVICE
RESOURCE BULLETIN **NC-51**



WOOD FUEL POTENTIAL FROM HARVESTED AREAS IN THE EASTERN UNITED STATES

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Manuscript approved for publication December 3, 1979

1980

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Wood is being reconsidered as a source of energy for both domestic and industrial needs. Estimates show that, although wood can supply only a very small percent of the Nation's energy requirement and therefore is not a panacea for the energy crisis, it can supply a significant amount of energy to selected municipalities, industries, and utilities (Houghton and Johnson 1976, Wahlgren and Ellis 1978).

In this paper, we assess the amount of residues and unutilized wood material potentially available from logging operations in the eastern United States (fig. 1). Salvage of these residue materials could greatly increase the utilization of available fiber. We focus on the potential wood fuel that may be available from harvested areas within reach of the skidder. Included are estimates from sources usually overlooked in forest inventories— cull sections, bark, tops, and limbs. Also included is material from rough and rotten trees and from trees cut on noncommercial and nonforest land. Although we feel that whole tree logging and field chipping would be used to salvage this material, a detailed investigation of the economic factors affecting its recovery is beyond the scope of this report. However, an economic analysis made for the Upper Peninsula of Michigan and northern Wisconsin showed tremendous quantities of material potentially available from all forest sources, with a significant amount available at competitive prices (Energy Research and Development Administration 1978).

Although we emphasize the potential use of residue as a fuel, much of the material may also be suitable for pulp, fiber, or chemicals. Eventual use will depend on the comparative cost of wood residue furnishes relative to other raw material sources.

Forest Resource Evaluation Research (FRER) reports acreage for certain defined land bases and timber volume (called inventory) for several defined tree classes. These breakdowns are based on land and tree quality and/or quantity characteristics. The timber

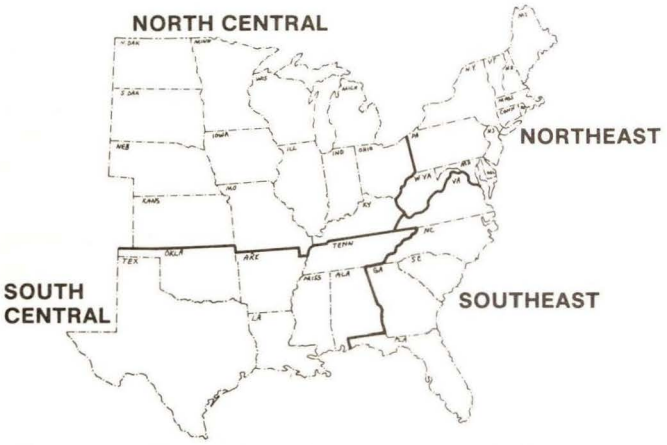

Figure 1.—*Regions of the eastern United States.*

inventory is not documented on some land bases such as noncommercial or nonforest land. Using information from the inventory of growing stock, rough, rotten, salvable dead, and mortality tree classes, we have estimated an amount of material that may be available from these trees on harvested areas. Also, the amount of timber removed annually for products is estimated by FRER by type of product and the land base and tree class categories from which the material came. Most of the timber removed comes from inventoried tree classes, but some harvest also comes from land bases for which no inventory is documented. Using timber products output data, we have estimated an associated volume of tops, limbs, logging residue, cull sections, and bark for the harvested tree volume. Cubic foot inventory and timber product removal data are presented in *Forest Statistics of the U.S., 1977*, and these data serve as the basis for the tables presented in this report (USDA Forest Service 1978).

We developed a key to show how the various land and tree categories are defined and to describe how the information may be used to develop a broader

picture of resource potential than is shown in traditional inventory tabulations. The key shows how the information flows through the land base and tree class categories (Part I) to the timber products output tables from which estimates of fuel potential are made (Part II) or, for some tree categories, how an estimate is made directly from inventory data (Part III). Several potential source categories (Part IV) are included for which we did not attempt to estimate a fuel amount.

For example, the land base is categorized as forest land or nonforest land depending on tree stocking and certain physical dimensions. Forest land is classified as either commercial or noncommercial based primarily on site quality. Commercial forest land contains a volume of growing stock trees and nongrowing stock trees or is not stocked at the time of inspection. Growing stock trees can be a source of fiber material through timber products harvest, mortality from natural causes, or removal in cultural operations or land clearing. Removal can also come by administrative edict. When an amount is documented as removed for timber products or left as logging residue, an associated amount of cull sections, tops, limbs, and bark can be estimated.

KEY TO FOREST SURVEY DATA[1]

Part I— Land and Resource Base

1. LAND BASE

   1A. FOREST LAND. Land at least 16.7 percent stocked by forest trees of any size, or formerly having such tree cover, and not currently developed for nonforest use. Includes chaparral areas in the West and afforested acres. The minimum forest area classified is 1 acre. Roadside, streamside, and shelterbelt strips of timber must have a crown width of at least 120 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classed as forest if less than 120 feet wide. (Forest statistics of U.S. (FSUS), Table 1.)[2]

   Go to (2)

   1B. NONFOREST LAND. Land that has never supported forests and land formerly forested but where forest use is now precluded by development for nonforest uses such as cropland, improved pastures, residential areas, and city parks. Includes narrow strips of timber (less than 120 feet wide) along improved roads, streams, and shelterbelts when adjoined by land developed for nonforest uses. (FSUS, Table 1.)

   Go to (6)

2. FOREST LAND

   2A. COMMERCIAL FOREST LAND. Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. This includes areas suitable for growing crops of industrial wood generally of a site quality capable of producing in excess of 20 cubic feet per acre of annual growth. Includes inaccessible and inoperable areas. (FSUS, Tables 2-5.)

   Go to (3)

   2B. NONSTOCKED AREAS. Commercial forest land less than 16.7 percent occupied with growing stock trees. Can support noncommercial growth. (FSUS, Tables 3-7.)

   Go to (11)

   2C. NONCOMMERCIAL FOREST LAND.

   (a) Unproductive— forest land incapable of yielding crops of industrial wood because of adverse site conditions. (FSUS, Tables 6,7.)

   Go to (6)

   (b) Productive-reserved— productive forest land withdrawn from commercial timber use through statute or administrative regulation, or exclusively used for growing christmas trees. (FSUS, Tables 6,7.)

   Go to (10)

3. COMMERCIAL FOREST LAND

   3A. GROWING STOCK. Net volume of growing-stock trees at least 5 inches in diameter at breast height (4.5 feet) from a 1-foot stump to a minimum 4.0-inch top diameter outside bark of the central stem or to the point where the central stem breaks into limbs. These are live trees of commercial species that meet specified standards of size and quality. Excludes rough, rotten, and dead trees, and trees of noncommercial species. (FSUS, Tables 10-12, 15, 16, 19, 20, 23, 25, 26, 29.)

   Go to (4)

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[1] *Categories for which cubic foot inventory volumes are reported are shown in capital letters in the key. Amounts estimated by applying factors to these volumes are shown in lower case letters.*

[2] *Tables cited show data source from* ***Forest Statistics of the United States,*** *1977, (FSUS) (USDA Forest Service 1978).*

3B. NONGROWING STOCK. Other than growing stock trees. The sound volume of rough, rotten, and salvable dead trees, including noncommercial species. Also includes saplings (trees less than 5 inches in diameter at breast height (4.5 feet)). (FSUS, Table 5.)

Go to (5)

4. GROWING STOCK SOURCE

4A. TIMBER PRODUCTS OUTPUT. The volume of products harvested from growing stock trees. (FSUS, Tables 47-67.)

Go to (7A)

4B. MORTALITY OF GROWING STOCK. The volume of sound wood in live sawtimber and poletimber trees dying from natural causes in a specified period. Natural causes include fire, insect, disease, animal, weather, and suppression. (FSUS, Tables 33, 45.)

Go to (8)

4C. OTHER REMOVALS. The net volume of growing-stock trees removed from the inventory by cultural operations (such as timber stand improvement), land clearings, and changes in land use and not utilized for timber products. (FSUS, Tables 47-67, 69.)

Go to (10)

5. NONGROWING STOCK SOURCE

5A. ROUGH TREES. Live trees of commercial species that do not contain at least one merchantable 12-foot saw log or two noncontiguous saw logs each 8 feet or longer, now or prospectively, because of roughness or poor form. All noncommercial species.

(a) TIMBER PRODUCTS OUTPUT. Volume of products harvested from rough trees. (FSUS, Tables 47-67.)

Go to (7B)

(b) Excess of harvested volume.

Go to (9)

5B. ROTTEN CULL TREES. Live trees of commercial species that do not contain a saw log, now or prospectively, because of rot (that is, when more than 50 percent of the cull volume of the tree is rotten).

(a) TIMBER PRODUCTS OUTPUT. Volume of products harvested from rotten trees. (FSUS, Tables 47-67.)

Go to (7B)

(b) Excess of harvested volume.

Go to (9)

5C. SALVABLE DEAD TREES. Standing or fallen dead trees that are considered merchantable by regional standards.

(a) TIMBER PRODUCTS OUTPUT. Volume of products harvested from salvable dead trees. (FSUS, Tables 47-67.)

Go to (7B)

(b) Excess of harvested volume.

Go to (9)

5D. SAPLINGS. Live trees of commercial species 1 to 5 inches in diameter at breast height (4.5 feet) and of good form and vigor. (FSUS, Tables 3, 8, 9.)

Go to (12)

6. NONCOMMERCIAL FOREST LAND AND NONFOREST LAND

Go to (7C)

Part II— The Following Potentials are Determined From Forest Survey Timber Harvest Studies

7. TIMBER PRODUCTS OUTPUT. All timber products cut from roundwood and all byproducts of wood processing plants. Roundwood products include logs, bolts, or other round sections cut from growing-stock trees, cull trees, salvable dead trees, trees on nonforest land, noncommercial species, sapling-size trees, and limbwood. Byproducts from primary processing plants include slabs, edgings, trimmings, miscuts, sawdust, shavings, veneer cores, clippings, and screenings of pulpmills that are used as pulp chips or other products. (FSUS, Tables 47-67.)

7A. TIMBER REMOVALS FROM GROWING STOCK. The volume of sound wood in live sawtimber and poletimber trees removed for forest products (including roundwood products), logging residues, and other removals. Roundwood products are logs, bolts, or other round sections cut from trees. Logging residues are the unused growing stock portions of cut trees plus unused trees killed by logging. Other removals are growing-stock trees removed by cultural operations (such as timber stand improvement), land clearing, and changes in land use. (FSUS, Tables 47-67.)

(a) PRODUCTS REMOVED. (THOUSAND CUBIC FEET) (FSUS, Tables 47-67.)

(a-1) Cull section wood
- 7.5 percent of sound, growing stock products for softwoods[3]
- 15.0 percent of sound, growing stock products for hardwoods

(a-2) Cull section bark
- 15.0 percent of cull wood

(a-3) Tops and limbs, including bark
- 30 percent of above ground tree weight for softwoods
- 35 percent of above ground tree weight for hardwoods

(b) LOGGING RESIDUES. Unused portions of growing stock from trees cut or killed by logging.

(a-1) Wood (FSUS Tables 47-67, 69.)

(a-2) Bark
- 15 percent of wood weight

7B. TIMBER PRODUCTS FROM NONGROWING STOCK (ROUGH, ROTTEN, AND SALVABLE DEAD TREES)

(a) PRODUCTS REMOVED. (THOUSAND CUBIC FEET) (FSUS, Tables 47-67.)

(a-1) Cull section wood
- 25 percent of product wood for rough softwood trees
- 30 percent of product wood for rough hardwood trees
- 50 percent of product wood for rotten trees
- 20 percent of product wood for salvable dead softwoods
- 30 percent of product wood for salvable dead hardwoods

(a-2) Cull section bark
- 15 percent of wood volume

(a-3) Tops and limbs, including bark
- 30 percent of above ground tree weight for softwoods
- 35 percent of above ground tree weight for hardwoods

7C. TIMBER PRODUCTS FROM OTHER SOURCES. Timber products output from trees on noncommercial or nonforest land.

(a) PRODUCTS REMOVED. (THOUSAND CUBIC FEET) (FSUS, Tables 47-67.)

(a-1) Cull section wood
- 25 percent of product wood for rough softwood trees
- 30 percent of product wood for rough hardwood trees
- 50 percent of product wood for rotten trees
- 20 percent of product wood for salvable dead softwoods
- 30 percent of product wood for salvable dead hardwoods

(a-2) Cull section bark
- 15 percent of wood volume

(a-3) Tops and limbs, including bark
- 30 percent of above ground tree weight for softwoods
- 35 percent of above ground tree weight for hardwoods

Part III—The Following Potentials are Determined by Estimating the Distribution on Harvested Areas Using Ratio of Growing Stock Harvested to Growing Stock Inventory

8. MORTALITY

8A. STEMWOOD. (THOUSAND CUBIC FEET) (FSUS, Tables 33, 45.)

(a) Stem bark
- 10 percent of stemwood

(b) Cull section wood
- 7.5 percent of sound growing stock products for softwoods
- 15 percent of sound growing stock products for hardwoods

(c) Cull section bark
- 10 percent of cull wood

(d) Tops and limbs, including bark
- 20 percent of above ground weight for softwoods
- 25 percent of above ground weight for hardwoods

9. EXCESS OF HARVESTED NONGROWING STOCK. The volume of nongrowing stock stem wood, cull sections, and tops and limbs estimated to be available on harvested areas but trees from which no products were removed.

(a) Stemwood
- Estimated from inventory ratio less products removed

(b) Stem bark
- 10 percent of stemwood

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[3]*Factor for converting cubic foot wood volume to dry weight was 27.5 pounds per cubic foot for softwoods and 33.0 pounds per cubic foot for hardwoods.*

(c) Cull section wood
- 7.5 percent of sound, growing stock products for softwoods
- 15 percent of sound, growing stock products for hardwoods

(d) Cull section bark
- 10 percent of cull wood

(e) Tops and limbs, including bark
- 20 percent of above ground weight for softwoods
- 25 percent of above ground weight for hardwoods

Part IV— Fuel Potentials are not Estimated for the Following Categories

10. OTHER REMOVALS SOURCES

10A. STAND IMPROVEMENT. Thinning, release cutting, girdling, weeding, or poisoning of unwanted trees aimed at improving growing conditions. (FSUS, Tables 47-67, 69.)

10B. PRODUCTIVE-RESERVED FOREST LAND. Forest land sufficiently productive to qualify as commercial timber land but withdrawn from timber utilization through statute or administrative designation. (FSUS, Tables 6,7.)

11. NONSTOCKED AREAS. Commercial timber land less than 10 percent occupied with growing stock trees. (FSUS, Tables 3-7.)

12. SAPLINGS. Live trees of commercial species 1 to 5 inches in diameter at breast height (4.5 feet) and of good form and vigor. (FSUS, Tables 3, 8, 9.)

METHODS AND FUEL ESTIMATES

The purpose of the key is to define and identify the sources of information for estimating the potential amount of wood fuel. Basically, we want to estimate the amount of fuel that could be obtained from current harvesting operations and to point out where gaps exist in the data base for estimating additional fuel potentials.

The bulk of the current timber harvest comes from growing stock timber on commercial forest land. After products are removed, the logging residue, cull sections, tops, and limbs of the harvested trees remain on the ground. This logging residue is specifically defined as material included in the growing stock portion of a harvested tree that was not removed as product. It is not the total accumulation of logging slash often thought of more generally as logging residue. The volume of products removed and the amount of logging residue are documented in studies by FRER personnel and are presented in timber product output tables. The additional volume of cull sections, tops, and limbs are estimated from factors developed from studies by Hitchcock *et al.* (1979), Keays (1975), and Young (1976) (tables 1 and 2).

In addition to this growing-stock harvest, nongrowing-stock trees are also available for harvest. The volume of these trees on harvested areas is determined as a ratio of growing stock harvested to growing stock inventory. We assumed that rough, rotten, and salvable dead trees are randomly scattered in Eastern forests and would be available for cutting. However, products are removed from some of these nongrowing-stock tree classes and potential fuel from these harvested cull trees would be available from cull sections, tops, and limbs (tables 3 and 4). Additionally, because all nongrowing stock trees estimated to be on the harvested acres are not cut for products, we estimate an amount in which the entire trees, including the stemwood, would be available for fuel. We call this the excess nongrowing stock (tables 5 and 6). This excess amount is the difference between the total amount of sound nongrowing-stock volume estimated to be on harvested areas less the amount of products removed from this class of trees.

Data are available showing both the total inventory and the amount of products harvested from growing-stock and nongrowing-stock tree classes on commercial forest land. Information is available for two other classes of growing-stock removals. First, an amount is removed for forest improvement cutting, cleared land, and land reserved for nontimber uses. No products are removed in these operations but the amount is documented as other removals from growing stock. Second, an amount is removed for mortality, i.e., the annual volume of growing stock that dies. All dead trees on harvested acres should be available for fuel. We have estimated an amount of mortality on harvested acres using the same ratio technique as with nongrowing-stock trees (table 7).

To this point, we have accounted for inventory and removals of growing stock, nongrowing stock, and mortality on commercial forest land. Information is available showing the amount of timber products cut from a category called "other sources", that is, from noncommercial and nonforest land. Because no inventory data are available for this class of material,

our estimate of fuel potential is limited to the cull sections, tops, and limbs from harvested trees (table 8). Here, we presume that the sound bole volumes were removed for products, and the estimated volume of tops, limbs, cull sections, and bark is associated with this removal.

Using the data bases, the ratio of growing stock harvested to growing stock inventory (to estimate the location of certain tree classes on harvested acres), and the softwood and hardwood conversion factors (to estimate the volume of cull sections, bark, tops, and limbs) we estimated the potential wood fuel from current harvesting operations in the eastern United States (table 9).

Table 1.—*Estimated potential fuel from harvested growing stock, 1976*

Region	Growing stock harvest		Cull sections[1]			Logging residues			Tops and Limbs	Total residue
			Wood	Bark[2]	Total	Wood	Bark[2]	Total		
	10^6 cu. ft.	*M tons*	*Thousand dry tons*[4]							
SOFTWOODS										
Northeast	395	5,431	407	61	468	888	133	1,021	3,315	4,804
North central	151	2,077	156	23	179	62	9	71	1,131	1,381
Subtotal	546	7,508	563	84	647	950	142	1,092	4,446	6,185
Southeast	1,720	23,645	1,773	266	2,039	1,944	292	2,236	13,486	17,761
South central	2,301	31,643	2,373	356	2,729	1,525	229	1,754	17,517	22,000
Subtotal	4,021	55,288	4,146	622	4,768	3,469	521	3,990	31,003	39,761
Total	4,567	62,796	4,709	706	5,415	4,419	663	5,082	35,449	45,946
HARDWOODS										
Northeast	542	8,941	1,341	201	1,542	2,645	397	3,042	8,002	12,586
North central	720	11,882	1,782	267	2,049	1,640	246	1,886	9,477	13,412
Subtotal	1,262	20,823	3,123	468	3,591	4,285	643	4,928	17,479	25,998
Southeast	631	10,417	1,563	234	1,797	2,552	383	2,935	8,998	13,730
South central	858	14,162	2,124	319	2,443	2,331	350	2,681	11,528	16,652
Subtotal	1,489	24,579	3,687	553	4,240	4,883	733	5,616	20,526	30,382
Total	2,751	45,402	6,810	1,021	7,831	9,168	1,376	10,544	38,005	56,380
SOFTWOODS AND HARDWOODS										
Total	7,318	108,198	11,519	1,727	13,246	13,587	2,039	15,626	73,454	102,326

[1]Cull section wood weight is estimated to be 7.5 percent of sound growing stock wood weight for softwoods and 15 percent for hardwoods.

[2]Bark is estimated to be 15 percent of the wood for cull sections and logging residue.

[3]Top and limb weight includes bark and foliage and is estimated to be 30 percent of the above-ground tree weight including stemwood, cull sections, and logging residue for softwoods and 35 percent for hardwoods.

[4]Factor for converting cubic foot wood volume to dry weight was 27.5 pounds per cubic foot for softwoods and 33.0 pounds per cubic foot for hardwoods.

Table 2.—*Estimated potential softwood fuel from harvested nongrowing stock, 1976*

Tree Class	Product removals[1]		Cull sections[2]			Tops and limbs[4]	Total
			Wood	Bark[3]	Total		
	10^3 cu. ft.	*M tons*[5]	*Thousand dry tons*[6]				
NORTHEAST							
Rough		65	16	3	19	40	59
Rotten	5,282	7	4	1	4	5	10
Salvable dead	6,348	87	18	3	20	52	72
Subtotal	11,630	159	38	7	43	97	141
NORTH CENTRAL							
Rough		21	5	1	6	13	19
Rotten	1,661	2	1	0	1	2	3
Salvable dead	1,444	20	4	1	5	12	16
Subtotal	3,105	43	10	2	12	27	38
Total	14,735	202	48	9	55	124	179
SOUTHEAST							
Rough		391	98	15	112	241	353
Rotten	31,564	43	22	3	25	32	57
Salvable dead	15,927	219	44	7	50	130	180
Subtotal	47,491	653	164	25	187	430	590
SOUTH CENTRAL							
Rough		132	33	5	38	81	119
Rotten	10,629	15	7	1	8	11	19
Salvable dead	1,583	22	4	1	5	13	18
Subtotal	12,212	169	44	7	51	105	156
Total	59,703	822	208	32	238	508	746
Total	74,438	1,024	256	41	193	632	925

[1]Does not include bark.

[2]Cull section wood is estimated to be 25 percent for rough trees, 50 percent for rotten trees, and 20 percent for salvable dead trees of soundwood volume (inventory or product volume).

[3]Bark is estimated to be 15 percent of wood volume.

[4]Tops and limbs, including bark and foliage, are estimated to be 30 percent of total above ground tree weight.

[5]Output of products from rough and rotten trees is estimated to be 90 percent from rough trees and 10 percent from rotten trees.

[6]Factor for converting cubic foot wood volume to dry weight is 27.5 pounds per cubic foot.

Table 3.—*Estimated potential hardwood fuel from harvested nongrowing stock, 1976*

Tree Class	Product removals[1]		Cull sections[2]			Tops and limbs[4]	Total
			Wood	Bark[3]	Total		
	10^3 cu. ft.	*M tons*[5]	*Thousand dry tons*[6]				
NORTHEAST							
Rough		228	68	10	79	184	262
Rotten	15,349	25	13	2	15	24	38
Salvable dead	8,417	139	42	6	48	112	160
Subtotal	23,766	392	123	18	142	320	460
NORTH CENTRAL							
Rough		1,167	350	53	403	939	1,342
Rotten	78,562	130	65	10	75	120	195
Salvable dead	23,295	384	115	17	133	309	442
Subtotal	101,857	1,681	530	80	611	1,368	1,979
Total	125,623	2,073	653	98	753	1,688	2,439
SOUTHEAST							
Rough		1,075	323	48	371	866	1,237
Rotten	72,408	120	60	9	69	111	180
Salvable dead	2,784	46	14	2	16	37	53
Subtotal	75,192	1,241	397	59	456	I,014	1,470
SOUTH CENTRAL							
Rough		489	147	22	169	394	563
Rotten	32,937	54	227	4	31	51	82
Salvable dead	10,446	172	52	8	60	139	198
Subtotal	43,383	715	226	34	260	584	843
Total	118,575	1,956	623	93	716	1,598	2,313
Total	244,198	4,029	1,276	191	1,469	3,286	4,752

[1]Does not include bark.

[2]Cull section wood is estimated to be 25 percent for rough trees, 50 percent for rotten trees, and 20 percent for salvable dead trees of soundwood volume (inventory or product volume).

[3]Bark is estimated to be 15 percent of wood volume.

[4]Tops and limbs, including bark and foliage, are estimated to be 30 percent of total above ground tree weight.

[5]Output of products from rough and rotten trees is estimated to be 90 percent from rough trees and 10 percent from rotten trees.

[6]Factor for converting cubic foot wood volume to dry weight is 27.5 pounds per cubic foot.

Table 4.—*Estimated potential softwood fuel from excess nongrowing stock on harvested areas, 1976*

(In thousand dry tons)[1]

Tree class	Stem section[2]			Cull section[3]			Tops and limbs[5]	Total
	Wood	Bark[4]	Total	Wood	Bark[4]	Total		
NORTHEAST								
Rough	418	63	481	105	16	120	258	859
Rotten	172	26	198	86	13	99	127	424
Subtotal	590	89	679	191	29	219	385	1,283
NORTH CENTRAL								
Rough	43	6	49	11	2	12	26	88
Rotten	19	3	22	10	1	11	14	47
Subtotal	62	9	71	21	3	23	40	135
Total	652	98	750	212	232	242	425	1,418
SOUTHEAST								
Rough	106	16	122	26	4	30	65	217
Rotten	48	7	55	24	4	27	35	118
Subtotal	154	23	177	50	8	57	100	335
SOUTH CENTRAL								
Rough	260	39	299	65	10	75	160	534
Rotten	229	34	264	115	17	132	170	565
Salvable dead	10	2	12	2	0	2	6	20
Subtotal	499	75	575	182	27	209	336	1,119
Total	653	98	752	232	35	266	436	1,454
Total East	1,305	196	1,502	444	67	508	861	2,872

[1]Factor for converting cubic foot wood volume to dry weight is 27.5 pounds per cubic foot.

[2]There was no salvable dead inventory in excess of product removals except in the South Central region.

[3]Cull section wood is estimated to be 25 percent for rough trees, 50 percent for rotten trees, and 20 percent for salvable dead trees of sound wood inventory volume.

[4]Bark is estimated to be 15 percent of wood volume.

[5]Tops and limbs, including bark and foliage, are estimated to be 30 percent of total above ground tree weight.

Table 5.—*Estimated potential hardwood fuel from excess nongrowing on harvested areas, 1976*

(In thousand dry tons)[1]

Tree class	Stem section[2]			Cull section[3]			Tops and limbs[5]	Total
	Wood	Bark[4]	Total	Wood	Bark[4]	Total		
NORTHEAST								
Rough	946	142	1,088	284	43	326	762	2,176
Rotten	694	104	798	347	52	399	645	1,842
Subtotal	1,640	246	1,886	631	95	725	1,407	4,018
NORTH CENTRAL								
Rough	344	52	395	103	16	119	277	790
Rotten	390	59	448	195	29	224	362	1,034
Subtotal	734	111	843	298	45	343	639	1,824
Total	2,374	357	2,729	929	140	1,068	2,046	5,842
SOUTH EAST								
Rough	1,404	211	1,615	421	63	485	1,131	3,230
Rotten	521	78	599	260	39	299	484	1,382
Subtotal	1,925	289	2,214	681	102	784	1,615	4,612
SOUTH CENTRAL								
Rough	2,656	388	3,054	797	120	916	2,138	6,108
Rotten	1,237	186	1,423	619	93	712	1,149	3,284
Subtotal	3,893	574	4,477	1,416	213	1,628	3,287	9,392
Total	5,818	863	6,691	2,097	315	2,412	4,902	14,004
Total East	8,192	1,220	9,420	3,026	455	3,480	6,948	19,846

[1]Factor for converting cubic foot wood volume to dry weight is 33 pounds per cubic foot.

[2]There was no salvable dead inventory in excess of product removals.

[3]Cull section wood is estimated to be 30 percent for rough trees and 50 percent for rotten trees of sound wood inventory volume.

[4]Bark is estimated to be 15 percent of wood volume.

[5]Tops and limbs, including bark and foliage, are estimated to be 35 percent of total above ground tree weight.

Table 6.—*Summary of estimated potential fuel from residues from conventional harvesting operations, by source, 1976*

(In thousand dry tons)

Region	Residue from harvested growing stock		Residue from harvested nongrowing stock		Residue from excess nongrowing stock		Total		
	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Total
Northeast	4,804	12,586	141	460	1,283	4,018	6,228	17,064	23,292
North Central	1,381	13,412	38	1,979	135	1,824	1,554	16,945	18,499
Subtotal	6,185	25,998	179	2,439	1,418	5,842	7,782	34,009	41,791
Southeast	17,761	13,730	590	1,470	335	4,612	18,686	19,812	38,498
South Central	22,000	16,652	156	843	1,119	9,392	23,275	26,887	50,162
Subtotal	39,761	30,382	746	2,313	1,454	14,004	41,961	46,699	88,660
Total	45,946	56,380	925	4,752	2,872	19,846	49,743	80,708	130,451

Table 7.—*Estimated potential fuel from mortality on harvested areas, 1976*

Region	Total mortality	Stem section			Cull section[1]			Tops and limbs[2]	Total residue
		Wood	Bark[3]	Total	Wood	Bark[3]	Total		
	10^3 cu. ft.	Thousand dry tons[4]							
SOFTWOODS									
Northeast	195,241	39.2	3.9	43.2	2.9	0.3	3.2	11.6	58.0
North Central	164,868	25.0	2.5	27.5	1.9	0.2	2.1	7.4	37.0
Subtotal	360,109	64.2	6.4	70.7	4.8	0.5	5.3	19.0	95.0
Southeast	300,194	160.9	16.1	177.0	12.1	1.2	13.3	47.6	237.8
South Central	184,660	124.8	12.5	137.3	9.4	0.9	10.3	36.9	184.5
Subtotal	484,854	285.7	28.6	314.3	21.5	2.1	23.6	84.5	422.3
Total East	844,963	349.9	35.0	385.0	26.3	2.6	28.9	103.5	517.3
HARDWOODS									
Northeast	501,604	84.8	8.5	93.3	12.7	1.3	14.0	35.8	143.1
North Central	500,242	109.7	11.0	120.7	16.4	1.6	18.1	46.2	185.0
Subtotal	1,001,846	194.5	19.5	214.0	29.1	2.9	32.1	82.0	328.1
Southeast	286,783	71.0	7.1	78.1	10.6	1.1	11.7	29.9	119.8
South Central	315,859	100.4	10.0	110.4	15.0	1.5	16.6	42.3	169.3
Subtotal	602,642	171.4	17.1	188.5	25.6	2.6	28.3	72.2	289.1
Total East	1,604,488	365.9	36.6	402.5	54.7	5.5	60.4	154.2	617.2
SOFTWOODS AND HARDWOODS									
Total East	2,449,451	715.8	71.6	787.5	81.0	8.1	89.3	157.7	1,134.5

[1]Cull section wood weight is estimated to be 7.5 percent of sound growing stock wood weight for softwoods and 15 percent for hardwoods.

[2]Top and limb weight for mortality trees is estimated to be 20 percent of the total above ground tree weight for softwoods and 25 percent for hardwoods.

[3]Bark is estimated to be 10 percent of the wood weight for mortality trees.

[4]Factor for converting cubic foot wood volume to dry weight was 27.5 pounds per cubic foot for softwoods and 33 pounds per cubic foot for hardwoods.

Table 8.—*Estimated potential fuel for timber harvested from other sources,*[1] *1976*

Region	Harvested	Other sources	Cull section[2]			Tops and limbs[2]	Total
			Wood	Bark	Total		
	10^6 cu. ft.	*M tons*	*Thousand dry tons*[3]				
SOFTWOODS							
Northeast	55	757	189.1	28.4	217.5	466.1	683.6
North Central	9	125	31.3	4.7	36.0	77.1	113.1
Subtotal	64	882	220.4	33.1	253.5	543.2	796.7
Southeast	86	1,178	294.4	44.2	338.5	725.5	1,064.1
South Central	67	926	231.4	34.7	266.1	570.3	836.4
Subtotal	153	2,104	525.8	78.9	604.6	1,295.8	1,900.5
Total East	217	2,986	746.2	112.0	858.1	1,839.0	2,697.2
HARDWOODS							
Northeast	30	496	148.9	22.3	171.2	399.6	570.8
North Central	95	1,565	469.3	70.4	539.8	1,259.5	1,799.3
Subtotal	125	2,061	618.2	92.7	711.0	1,659.1	2,370.1
Southeast	26	436	130.7	19.6	150.3	350.6	500.9
South Central	57	939	281.7	42.3	324.0	755.9	1,079.9
Subtotal	83	1,375	412.4	61.9	474.3	1,106.5	1,580.8
Total East	208	3,436	1,030.6	154.6	1,185.3	2,765.6	3,950.9
SOFTWOODS AND HARDWOODS							
Total East	425	6,422	1,776.8	266.6	2,043.4	4,604.6	6,648.1

[1]Other sources— timber products cut from trees on noncommercial or nonforest land.

[2]Factors for cull section, tops and limbs, and bark are the same as for harvested rough trees in tables 2 and 3.

[3]Factor for converting cubic foot wood volume to dry weight was 27.5 pounds per cubic foot for softwoods and 33 pounds per cubic foot for hardwoods.

Table 9.—*Distribution of estimated potential fuel by source and area, eastern United States, 1976*

Source	Total		Total residue		North				South			
			Softwoods	Hardwoods	Softwoods		Hardwoods		Softwoods		Hardwoods	
	M tons	*Per-cent*[1]	*M tons*	*M tons*	*M tons*	*Per-cent*[1]	*M tons*	*Per-cent*[1]	*M tons*	*Per-cent*[1]	*M tons*	*Per-cent*[1]
Harvested growing stock	102,326	74	45,946	56,380	6,185	6	25,998	25	39,761	39	30,382	30
Harvested nongrowing stock	5,677	4	925	4,752	179	3	2,439	43	746	13	2,313	41
Excess nongrowing stock	22,718	16	2,872	19,846	1,418	6	5,842	26	1,454	6	14,004	62
Mortality	1,134	1	517	617	95	8	328	29	422	37	289	26
Harvested other sources	6,648	5	2,697	3,951	797	12	2,370	36	1,901	29	1,581	24
Total	138,503		52,957	85,546	8,674		36,977		44,284		48,569	

[1]Portion of total residue by area and species within each individual residue source.

CONVERSION FACTORS

Reliable factors are available to convert cubic foot volumes to a weight basis and to estimate the weight of accompanying tops, limbs, bark, and cull sections. The factors used in this report have been developed from many different weight and biomass studies that predict the tonnage of these components based on the weight of the sound tree bole (growing stock) (Hitchcock *et al.* 1979, Keays 1975, Young 1976). These factors provide reasonable estimates of the total forest inventory tonnage and bring into perspective the opportunity for providing increased amounts of wood fiber for fuel and other uses.

More reliable weight predictions will be possible when individual species regression equations are incorporated into forest survey data analysis systems and when the potential amount of material available from intermediate cuts is estimated. The Forest Resource Evaluation Program tree growth projection system developed at the North Central Forest Experiment Station offers the opportunity to predict potential yields from various cutting schedules (USDA Forest Service 1979). For the time being, however, estimates must be made from available information.

The various factors used to estimate unreported tonnages are shown in the Key and in table footnotes. Basic estimates of tree component proportions are patterned after Young's composite for all species (fig. 2) (Young 1977).

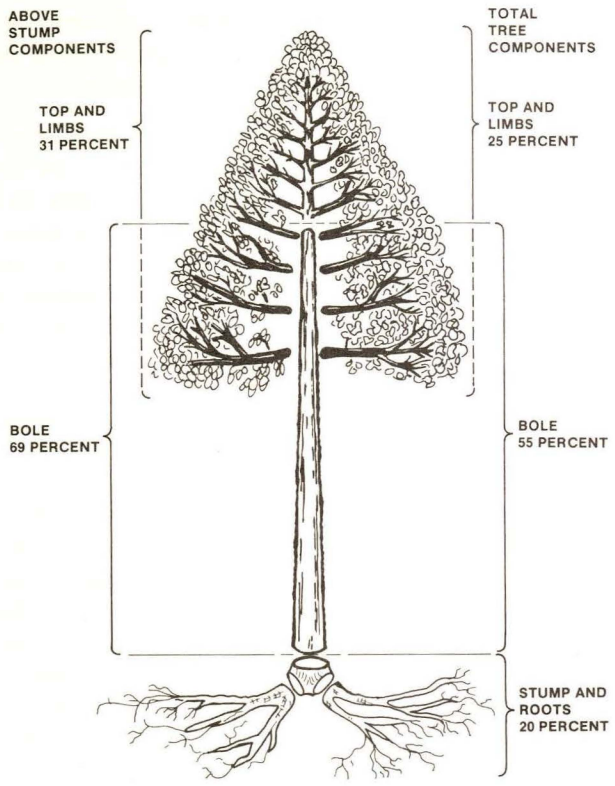

Figure 2.—*Fresh weight components of complete trees and shrubs.*

DISCUSSION

Using inventory data for 1976, we estimate a potential fuel source of 138 million dry tons a year from forest residues in the eastern United States. This amount would be available from harvested acres if all cull sections, logging residue, tops, and limbs from trees cut for products were salvaged, and if all rough, rotten, salvable dead, and mortality trees on harvested areas were removed at the time of cutting. The 138 million tons has an energy potential of 2.35 quads Btu.

Some aspects of the determination of fuel potential from harvested acres would suggest a much larger amount might be available from some sources. The extent that some mortality is concentrated in burned or insect-infected areas rather than randomly scattered might reduce the amount expected to be on harvested acres. On the other hand, if these concentrations are not salvaged because of low product marketability, a fuel market might offer the opportunity to salvage these concentrated volumes, causing a somewhat larger amount to be readily available.

We did not estimate the potential from noncommercial timber stand improvement operations even though an estimate is made of the amount removed from growing stock. In the first place, the data are confounded with amounts removed through withdrawals from utilization. Secondly, the potential amount of fiber available from areas needing thinning or other cultural work is undoubtedly huge when compared to the amount actually cut, whether products are removed or not. But, determination of an amount would require more detailed knowledge of stand stocking and a harvest technology for removing material from partial cuts without damaging the residual stand. The use of this material for fuel could provide the incentive where markets have been lacking in the past.

Material that could be removed from nonstocked areas and logging residue from nongrowing-stock trees might add additional amounts to the estimate. The latter would be material included in the inventory but not removed in harvesting products from

this source. A significantly larger but undocumented amount of material could also be available from the noncommercial and nonforest land sources.

From a practical standpoint, the lack of a harvest technology to remove whole trees intact in partial cuts or to remove tops, limbs, and cull trees in a separate relogging operation would reduce the potential fuel from growing-stock harvests. How serious this might be is unknown. Both situations are being researched at the Forestry Sciences Laboratory in Houghton, Michigan (Biltonen *et al.* 1976).

SUMMARY

Two-thirds of the forest residue in the eastern United States is concentrated in the South where it is equally divided between softwoods and hardwoods. The remaining one-third of the residue is in the North and is 80 percent hardwood and 20 percent softwood. Material from harvested growing stock accounts for nearly 75 percent of the total. Another 16 percent comes from rough, rotten, and salvable dead trees from which products were not taken. All of this residue adds up to 138 million tons of material per year that could be used for fuel if conditions and technology existed to get it out of the forests.

Although wood is not the only answer to the world's energy problem, significant plant investments are being made to use it to satisfy industrial, utility, and municipal energy needs. This trend should continue as the price of alternative fuels increases and as the infrastructure to supply and utilize wood fuel develops.

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Estimates amount of wood fiber that could be available for fuel from forest residues on harvested areas in the eastern United States. Includes a key to resource data published by the USDA Forest Service and factors for estimating amounts of cull, bark, tops, and limbs from inventory and product output tabulations.

KEY WORDS: Key to Forest Resource Statistics, conversion factors, forest resource definitions, forest residue utilization.

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Plant a tree...trees give oxygen.